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WINTER WHEAT YIELD ESTIMATION FOR ROMANIA, BASED ON NORMALIZED DIFFERENCE VEGETATION INDEX DATA AVAILABLE ON MARSOP SITE

ESTIMAREA RECOLTELOR/PRODUCŢIILOR DE GRÂU DE TOAMNĂ PENTRU ROMÂNIA PE BAZA DATELOR DISPONIBILE PE SITE-UL MARSOP REFERITOARE LA INDICELE DIFERENŢIAL NORMALIZAT AL VEGETAŢIEI

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Abstract

The model outputs from extranet MARSOP of MARS unit from JRC-ISPRA were not designed for a direct use as yield forecast. This study investigated if there is any simple possibility for an external user to obtain early yield estimation for different regions of Romania, based on remote sensing data, also available on this site.
The Normalized Difference Vegetation Index (NDVI) calculated from SPOT Vegetation data available on MARSOP site explained for the southern half of Romania more than 60% of the variation in the wheat yields from EUROSTAT database.
Exclusion of an outlier (year 2007) improved the forecast capacity (R2 = 0.8 at national level) of the NDVI from the beginning and mid April. In some regions, quadratic regressions were able to provide a better fit. The simulated leaf area index and relative soil moisture proved to be helpful for an earlier interpretation of a year as a possible outlier.

Key words: winter wheat, NDVI, SPOT-Vegetation, MARSOP, Romania, yield.

INTRODUCTION

For the implementation of the Common Agricultural Policy, the European Commission needs timely information on the agricultural production to be expected in the current season. This is a main concern of the MARS-project (Monitoring Agriculture through Remote Sensing techniques). The MARS project is one of the projects of the Directorate General Joint Research Centre (JRC) of the European Commission in Ispra (Italy).

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The extranet site <http://www.marsop.info>of the Monitoring Agricultural Resources Unit (MARS) of Institute for Protection and Security of the Citizen from JRC-Ispra offers a wide variety of information about the current agricultural season in Europe and other important agricultural areas in the world. Available products include:

- maps of weather indicators based on observations and numerical weather models;
- maps and time profiles of crop indicators based on agro-meteorological models;
- maps of vegetation indices and cumulated dry matter based on remote sensing images.

The core of the Crop Growth Monitoring System (CGMS) is the WOFOST model (Lazar and Genovese, 2004; Savin et al., 2004), but the outputs of the model are not used directly for the yield forecast. These inputs in various combinations are used in a complicated statistical platform (level 3 of CGMS) to detect the most similar years with the current year for the target area. The detrended statistical yields from these years are weighted with a similarity index and averaged to propose several possible forecasts to the country analyst. The recalibration of the model for Romania with local data for the winter wheat cultivated during the years 1990-2009, the operational use of the already implemented options for autumn start of the simulation (S a v i n et al., 2004) and winter kill (L a z ă r et al., 2005) is expected to result in model outputs that are directly comparable with the observed values. For the moment, the model outputs, updated each 10 days on the MARSOP extranet are very useful for understanding the crop status and compare the situation from the current year with the previous and long term average. This study was aimed to find a simple way for the early estimation of the wheat yield for Romania and its main statistical regions, based on remote sensing data available in MARSOP extranet.

The remote sensing data available come from three sensors:

– AVHRR (Advanced Very High Resolution Radiometer);
– SPOT VEGETATION,
– MODIS.

The MODIS images have the best resolution (250 m pixel size) but for the moment in MARSOP there are not enough years available for a time series analysis. The JRC MARS-unit built up an archive of AVHRR-images starting from 1989 and from November 2000 onwards, the Belgian organisation VITO (Vlaamse Instelling voor Technologisch Onderzoek – a member of the MARSOP-consortium) became responsible for the processing of these data at the European level.

Since November 2000 the MCYFS also makes use of the low resolution imagery of the system SPOT VEGETATION. The series of SPOT-satellites are a French initiative with minor contributions of the Belgian, Italian and Swedish public and private sectors. SPOT1, 2 and 3 were respectively launched in 1986, 1990 and 1993 and only carried the high resolution sensor HRV with 20m-resolution in the multi-spectral mode (Green, Red, Near InfraRed) and 10m for the panchromatic band. With SPOT4 which was placed in orbit in 1998, the HRV was extended with a Blue band and renamed to HRVIR, but also a new Low Resolution sensor was added: VEGETATION (or VGT for short). In 2002, SPOT5 was launched successfully with as payload an upgraded version of the HRVIR (10m/4m-resolution) and a copy of the previous VGT-sensor. The methodology regarding the remote sensing data used in CGMS and available on MARSOP site is described by R o y e r and G e n o v e s e (2004).

The maximum values from each image are composed for a month or „dekade" period. The first two „dekades" of each month comprise 10 days, while for the third one the number of days varies with the month (8, 9, 10 or 11).

Normalized difference vegetation index (NDVI) is computed as ratio between the difference and the sum of near infrared and red bands. In addition to NDVI other indicators are calculated (B a r u t h et al., 2008) and available on MARSOP site: the fraction of absorbed photo synthetically active radiation (fAPAR) (M y n e n i, 1994) is derived by a model based approach after Gobron (2006) for SPOT and based on the CYCLOPES approach (B a r e t et al., 2007) for NOAA. Using the fAPAR, dry matter productivity (DMP) following the approach from M o n t e i t h (1972). They also aggregated for five land use classes based on CORINE landcover (natural grasslands, non irrigated arable land, pastures, permanent irrigated areas and rice fields) aria over different statistical units (NUTS).

The low resolution products were used for a lot of studies including crop phenology (e.g. K l i s c h et al., 2006; L u and G u o, 2008) and there are numerous examples of successful applications of these products for yield monitoring at country or regional level like E e r e n s et al. (2000) for Belgium, T y c h o n et al. (2000) for Sahel area, and B a l a g h i et al. (2008) for Morocco.

MATERIALS AND METHODS

The inputs for study were self-limited to the publicly available data on internet. The yearly yield data for wheat (crop C1120: Common wheat and speltoides) were downloaded from EUROSTAT<http://nui.epp.eurostat.ec.europa.eu/nui/show.do?dataset=agr_r_crops& lang=en> for Romania (RO00) and seven statistic regions. The remote sensing data were downloaded from the MARSOP extranet <http://www.marsop.info> Even if the NDVI for SPOT Vegetation data (non irrigated arable land class) are available only since 1995; this data set was preferred for the study due to the lack of gaps. The data can be exported as comma separated values (.csv) files in packs of maximum six years per region.

The correspondence between the territorial units used in EUROSTAT database and those used in MARSOP (using NUTS version 2003) was:

MARS	EUROSTAT	Area	Counties
RO00	RO	ROMANIA	
RO01	RO21	North-East	Bacau, Botosani, Iasi, Neamt, Suceava, Vaslui
RO02	RO22	South-East	Braila, Buzau, Constanta, Galati, Tulcea, Vrancea
RO03	RO31	South	Arges, Calarasi, Dambovita, Giurgiu, Ialomita, Prahova, Teleorman
RO04	RO41	South-West	Dolj, Gorj, Mehedinti, Olt, Valcea
RO05	RO42	West	Arad, Caras-Severin, Hunedoara, Timis
RO06	RO11	North-West	Bihor, Bistrita-Nasaud, Cluj, Maramures, Satu Mare, Salaj
RO07	RO12	Central	Alba, Brasov, Covasna, Harghita, Mures, Sibiu

The Bucharest-Ilfov area was not considered in this study mainly due to the continuous reduction of agricultural surfaces. Only the codes from MARSOP are used in this study.

Most of the statistical yield data presented no trend along the considered period. For the Western region of Romania a weak trend was visible (R^2 about 0.2) but its influence was neglected. Linear regressions between NDVI from a specific „dekade" or averages of several „dekades" and statistical yields were performed for each statistic unit using data from all available years. When an obvious outlier was detected linear regressions were also performed excluding that year and an explanation for the crop dynamics was sought in the winter wheat simulations for that specific year. In some cases polynomial regressions were also used.

RESULTS AND DISCUSSIONS

At the country level, the highest percent of yield variance explained by NDVI through linear regressions was 62% (Table 1). For South-Eastern (RO02) and South (RO03) regions the R^2 was about 0.68, followed by South-Western (RO04) region with a maximum of R^2 of 0.62. For North-Western (RO06) region the highest R^2 was about 0.30, while for the Central (RO07) and North-Eastern (RO01) regions it was 0.53 and 0.46 respectively. Those maximal values for R^2 were obtained for the last third of May, except South-Western region (RO04) where it was obtained for the mid of May and the Western (RO05) region where the best fit ($R^2 = 0.47$) was achieved for the mid of June. In several cases, a better fitting was provided by quadratic regressions like in cases of South-Eastern (RO02) and South (RO03) regions were percent of yield variance explained by NDVI from end of May was above 81% and 74% respectively (Figure 1).

The analysis of the graphs for each 10 days period (not included in this paper) indicated the year 2007 as a clear outlier. The simulated data from MARSOP indicate for 2007, an early massive increase of leaf area index already visible in March (in Figure 2 the situation for RO04) followed by continuous reduction of simulated relative soil moisture (Figure 3) till beginning of May (about 30% bellow long term average). The precipitation from mid May raised the level of relative soil moisture with 10% but the impact of the drought on the crop was already high.

Table 1

The slope, intercept and R^2 values for the regressions between „dekadal” NDVI and the statistical yield for winter wheat cultivated in various regions of Romania between 1999-2008
(*Maximum R^2 values for each region are shown in bold)*

Area	Regression	Mar III	Apr I	Apr II	Apr III	May I	May II	May III	June I	June II	June III
RO00	Slope	3.71	4.14	4.22	4.86	7.07	8.85	10.64	6.56	5.95	7.02
	Intercept	1.32	0.97	0.66	0.04	-1.55	-2.81	-3.98	-1.46	-1.05	-1.62
	R^2	0.14	0.12	0.33	0.23	0.20	0.34	**0.62**	0.25	0.22	0.29
RO01	Slope	3.19	7.98	2.11	4.28	4.78	5.72	9.30	4.27	8.37	7.07
	Intercept	1.47	-0.31	1.53	0.29	-0.33	-1.03	-3.40	-0.22	-2.88	-2.04
	R^2	0.11	0.24	0.08	0.19	0.13	0.18	**0.46**	0.08	0.39	0.39
RO02	Slope	5.64	7.23	5.16	5.22	6.76	7.14	12.49	8.41	7.73	6.27
	Intercept	0.65	-0.11	0.29	-0.04	-1.22	-1.59	-4.58	-2.36	-1.92	-1.08
	R^2	0.22	0.26	0.34	0.21	0.23	0.28	**0.60**	0.35	0.31	0.21
RO03	Slope	4.72	5.12	5.55	6.04	8.10	10.38	12.18	7.71	4.03	4.16
	Intercept	0.87	0.44	-0.15	-0.66	-2.20	-3.69	-4.79	-2.13	0.19	0.20
	R^2	0.18	0.20	0.42	0.29	0.32	0.53	**0.68**	0.26	0.09	0.10
RO04	Slope	4.92	5.10	4.56	7.28	10.78	10.40	8.72	4.54	3.48	5.20
	Intercept	0.54	0.19	0.15	-1.64	-4.17	-4.12	-3.14	-0.48	0.19	-0.70
	R^2	0.16	0.20	0.40	0.32	0.43	**0.62**	0.54	0.16	0.08	0.20
RO05	Slope	2.27	2.74	2.11	3.57	4.53	4.64	4.33	3.63	4.86	3.67
	Intercept	2.29	1.95	2.09	1.11	0.29	0.13	0.30	0.82	0.03	0.83
	R^2	0.18	0.19	0.24	0.39	0.17	0.22	0.32	0.27	**0.47**	0.22
RO06	Slope	3.50	2.72	2.06	4.33	4.16	6.14	7.81	6.25	4.94	4.99
	Intercept	1.66	1.79	1.93	0.47	0.33	-1.10	-2.27	-1.22	-0.37	-0.37
	R^2	0.24	0.08	0.13	0.23	0.07	0.11	**0.30**	0.25	0.22	0.29
RO07	Slope	4.26	3.47	1.99	4.19	6.39	2.42	7.39	3.08	4.25	3.86
	Intercept	1.42	1.52	1.90	0.47	-1.14	1.20	-2.31	0.66	-0.23	0.11
	R^2	0.44	0.21	0.22	0.51	0.18	0.04	**0.53**	0.12	0.16	0.28

After the removal of the values for 2007, the R^2 increased visibly (Table 2) except the region RO02 were it decreased for end of May at 0.65. For the Central region (RO07) the best fit was obtained at the end of March ($R^2 = 0.79$). For the other regions the maximum R^2 was obtained for the first or mid April (values between 0.5 for RO01 and 0.92 for RO04). The R^2 for the regression at national level was 0.8. Also for this reduced data sets, in some cases the quadratic functions permitted a better description of the relationship between statistical yield and NDVI. Some of these situations are presented in Fig. 4 and Fig. 5.

The shift of the highest R^2 towards first half of spring suggest that LAI from April may be a good early indicator for a probable level of yield, but adverse conditions may drastically reduce the real yield. On the other hand, favourable conditions, especially during grain filling period will result in an increased yield. Using only remote sensing data or even combined with data from agro-meteorological infrastructure (M i c a l e and G e n o v e s e, 2004) may not be enough to timely detected the „outlier” years. The simulation models may bring a better understanding of the situation and their outputs may help finding earlier in finding a similar situation in the past years.

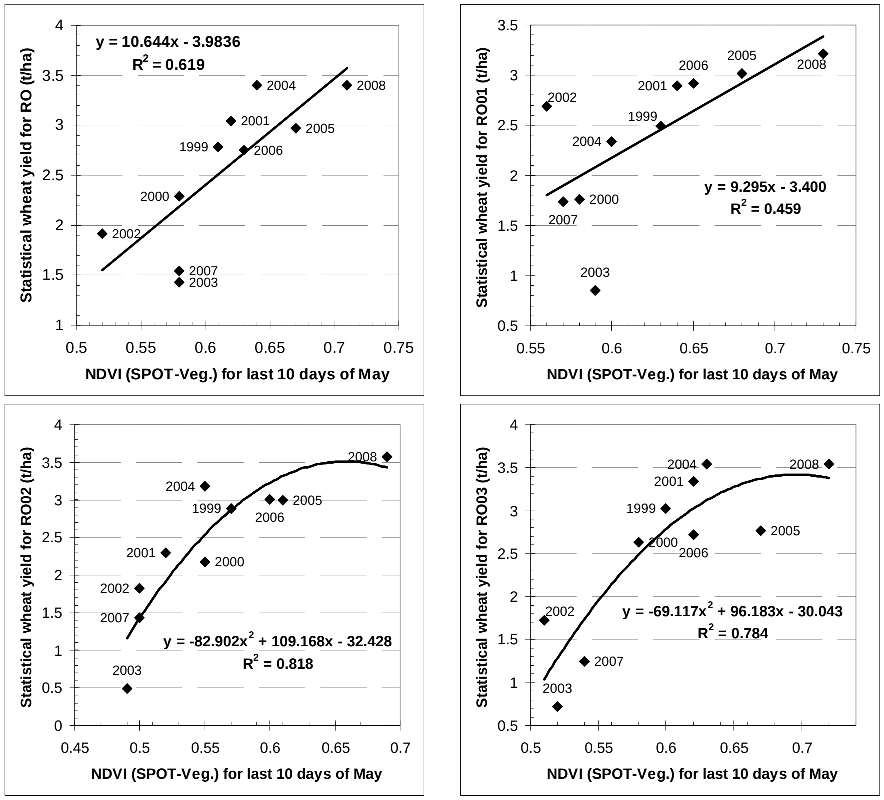

Fig. 1 – Estimation of winter wheat yields (EUROSTAT data) based on Normalised Difference Vegetation Index (NDVI) composed for last 10 days of May, aggregated for the non-irrigated areas of whole Romania (RO) and the three eastern regions (RO01, RO02 and RO03)

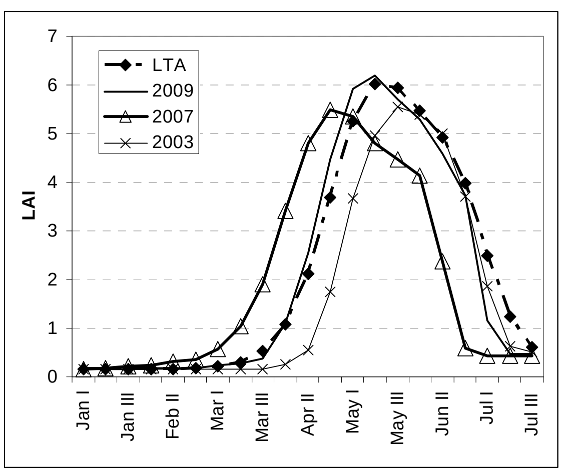

Fig. 2 – Leaf Area Index (LAI) for winter wheat simulated with WOFOST model for the region RO04 (South Western region) in 2003, 2007, 2009 and the long term average (LTA)

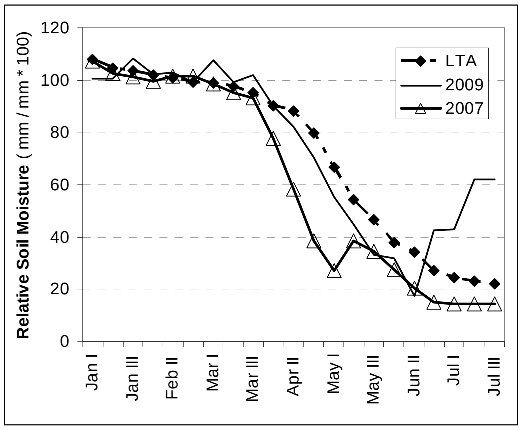

Fig. 3 – Relative Soil Moisture (RSM) for winter wheat simulated with WOFOST model for the region RO04 (South Western region) in 2007, 2009 and the long term average (LTA)

Table 2

The slope, intercept and R^2 for the regressions between „dekadal" NDVI and the statistical yield for winter wheat cultivated in various regions of Romania between 1999-2008 (excluding year 2007) *(Maximum R^2 values for each region are shown in bold)*

Area	Regression	Mar III	Apr I	Apr II	Apr III	May I	May II	May III	Jun I	Jun II	Jun III
RO00	Slope	6.43	10.77	6.01	7.63	8.45	10.51	9.64	6.09	4.77	5.92
	Intercept	0.59	-1.33	0.03	-1.22	-2.22	-3.68	-3.29	-1.07	-0.25	-0.87
	R^2	0.49	0.76	**0.80**	0.65	0.37	0.61	0.64	0.28	0.17	0.26
RO01	Slope	4.16	12.04	2.89	5.27	5.85	7.35	8.89	4.91	8.16	6.61
	Intercept	1.29	-1.54	1.32	-0.09	-0.84	-1.91	-3.13	-0.54	-2.68	-1.72
	R^2	0.19	**0.50**	0.16	0.31	0.20	0.30	0.41	0.12	0.41	0.36
RO02	Slope	6.43	10.19	6.52	7.67	7.63	9.11	12.01	7.75	6.90	5.13
	Intercept	0.54	-0.95	-0.10	-1.00	-1.55	-2.53	-4.29	-1.91	-1.42	-0.39
	R^2	0.32	0.52	0.57	0.46	0.33	0.48	**0.65**	0.33	0.23	0.13
RO03	Slope	8.68	10.28	7.39	8.78	8.70	10.78	11.16	6.23	2.04	2.52
	Intercept	-0.26	-1.38	-0.81	-1.88	-2.40	-3.78	-4.11	-1.12	1.46	1.24
	R^2	0.61	0.78	**0.86**	0.68	0.46	0.73	0.65	0.20	0.03	0.04
RO04	Slope	7.64	9.27	5.87	9.56	9.44	9.84	7.73	5.07	3.96	5.96
	Intercept	-0.20	-1.27	-0.25	-2.65	-3.22	-3.63	-2.39	-0.63	0.07	-0.95
	R^2	0.51	0.82	**0.92**	0.77	0.47	0.80	0.60	0.28	0.16	0.38
RO05	Slope	4.31	7.60	3.19	5.10	7.02	5.97	4.89	4.24	5.26	4.16
	Intercept	1.64	0.04	1.64	0.34	-1.18	-0.66	-0.01	0.49	-0.17	0.58
	R^2	0.53	**0.85**	0.50	0.74	0.38	0.36	0.44	0.39	0.60	0.31
RO06	Slope	6.29	12.56	3.44	6.09	6.88	6.01	8.64	7.60	5.48	5.31
	Intercept	0.84	-1.77	1.41	-0.40	-1.23	-0.97	-2.74	-2.02	-0.66	-0.52
	R^2	0.63	**0.74**	0.33	0.44	0.18	0.11	0.39	0.39	0.29	0.36
RO07	Slope	6.22	9.05	2.57	4.79	8.53	3.86	7.66	5.02	4.87	3.95
	Intercept	0.88	-0.39	1.70	0.19	-2.40	0.30	-2.46	-0.63	-0.63	0.08
	R^2	**0.79**	0.78	0.34	0.66	0.30	0.10	0.60	0.27	0.22	0.31

In the case of RO01, RO05 and RO06 a partial regain of the forecasting capacity of the NDVI is noticed for the mid of June.

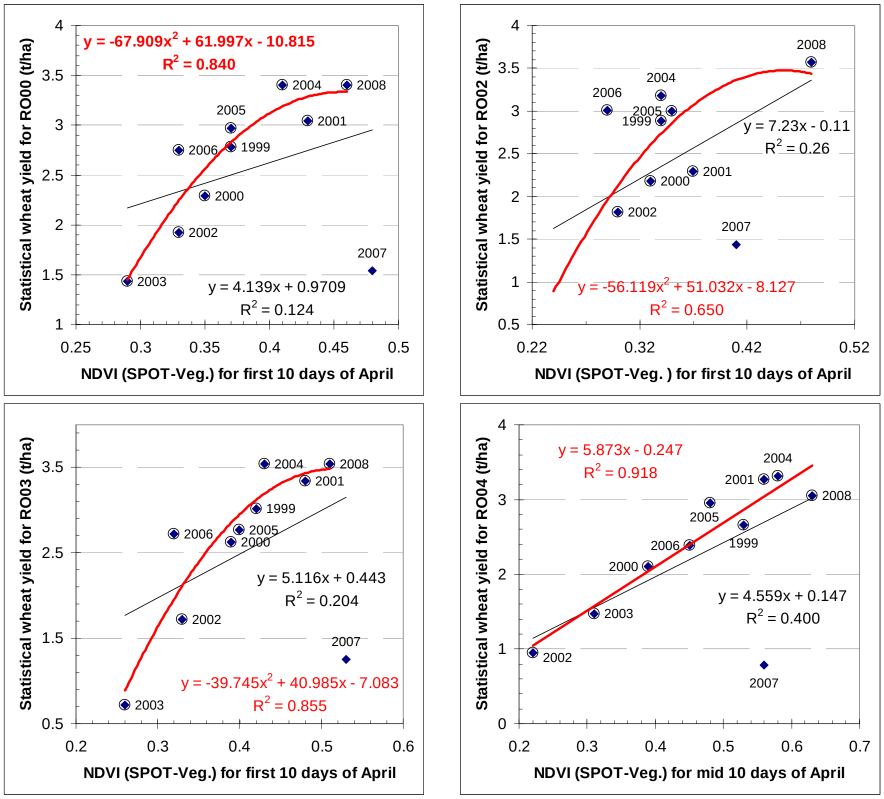

Fig. 4 – Estimation of winter wheat yields (EUROSTAT data) based on Normalised Difference Vegetation Index (NDVI) composed for 10 days from April, aggregated for the non-irrigated areas of whole Romania (RO) and three regions (RO02, RO03 and RO04)

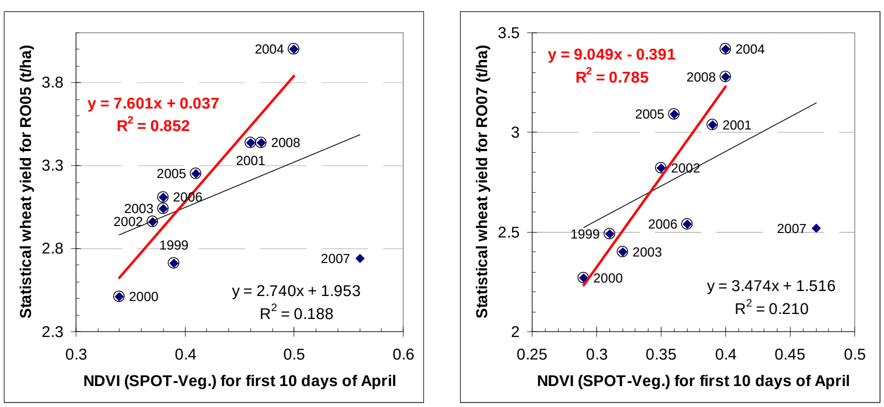

Fig. 5 – Estimation of winter wheat yields (EUROSTAT data) based on Normalised Difference Vegetation Index (NDVI) composed for the first 10 days from April, aggregated for the non-irrigated areas of regions RO05 (Vest) and RO05 (Central)

CONCLUSIONS

The NDVI calculated from SPOT Vegetation data available on MARSOP site for the southern half of Romania explained more than 60% of the variation in the wheat yields from EUROSTAT database.

Exclusion of an outlier (year 2007) improved the forecast capacity (R^2 = 0.8 at national level) of the NDVI from the beginning and mid April.

The quadratic regressions were able in some regions to provide a better fit.

The simulated leaf area index and relative soil moisture can be helpful for an earlier interpretation of a year as possible outlier.

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